330

A PHOTOELECTRIC CURRENT METER

SPECIAL SCIENTIFIC REPORT—FISHERIES No. 330

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

EXPLANATORY NOTE

The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for official use of Federal, State or cooperating agencies and in processed form for economy and to avoid delay in publication.

United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, Arnie J. Suomela, Commissioner

A PHOTOELECTRIC CURRENT METER

by

H. C. Boyar
Fishery Research Biologist
Bureau of Commercial Fisheries
Biological Laboratory
Boothbay Harbor, Maine

and

F. E. Schueler
30 Albermarle Road
Waltham, Massachusetts

United States Fish and Wildlife Service
Special Scientific Report--Fisheries No. 330

Washington, D. C.
March 1960

TABLE OF CONTENTS

A PHOTOELECTRIC CURRENT METER

by

H. C. Boyar and F. E. Schueler

ABSTRACT

A need for an accurate measure of water velocity in circular rotating tank experiments with marine fishes led to the construction of a current meter, in which the revolutions of a propeller are detected photoelectrically. Its design and operation permit measurements to be made of the currents encountered by fishes in laboratory and field tests.

INTRODUCTION

Studies designed to determine maximum swimming speed and endurance of fishes have resulted in the development of various types of rotating circular troughs, popularly known as "fish wheels." Most of these wheels operate on one basic principle. Fish are placed in the water-filled trough section of the wheel, which is then rotated about a vertical axis. If a fish is positively rheotactic, it will swim in a direction opposite to the water movement, expending enough energy to maintain a position with respect to a fixed object in its environment.

To determine swimming speed of a fish, the velocity of the water under different test conditions must be known. In the past, various improvised devices and techniques have been used to obtain this information. As a result, some reported swimming speeds may be estimates rather than absolute values. Some recent investigators have used devices which give accurate data, but which either are useful only under certain conditions or have one or more undesirable features. With continued interest in swimming-speed studies, particularly with the use of the fish wheel, there is a need to measure water currents accurately under many types of laboratory and field conditions.

A number of methods have been used to determine water velocities in fish wheels. Regnard (1893), one of the first fish behaviorists and probably the first investigator to use a rotating-type vessel, recorded how long it took a fixed point on the vessel to travel a given distance. Fry and Hart (1948) determined the water velocity in a rotating circular trough by measuring the time required for a ball of cotton to make one revolution in the trough chamber. They stated that the final speeds as measured by the trough were estimates rather than absolute values. Davidson (1949) measured the water velocity in a circular rearing pond by means of a small cork weighted with a drag of the desired length, but so constructed as to float with the water surface. She recorded how long it took the cork to move a given distance. In addition, she measured how long it took bubbles and "smaller floating objects" to travel the same distance.

In the last few years, several other methods have been employed. Paulik, DeLacy, and Stacy (1957) determined water velocities in their fish wheel with the aid of a Leupold and Stevens midget current meter. Brett, Hollands, and Alderdice (1958) reported that the water velocity within their rotating trough could be measured accurately by determining the velocity of a small circular plastic disk having needle tips radically arranged and floating on the water surface with the trough in motion. They confirmed their results by recording how long it took drops of dye to move the same distance.

Swimming-speed studies of herring (Clupea harengus) using a circular rotating trough are in progress at the Bureau of Commercial Fisheries Biological Laboratory at Boothbay Harbor, Maine. Fish are placed in a specially designed cage (20 inches long by 3 3/4 inches wide by 7 inches high), so constructed that it fits within a section of the rotating trough, but permits water to enter and leave. The cage provides excellent opportunity for observation of fish behavior. It also eliminates visual reference points on the trough. To determine the water velocity through the cage (and if desired, the velocity of the water in the trough itself), it was necessary to have a device which could fit easily within the cage and could be used in salt water.

Previous methods for water velocity determinations in circular tank experiments are subject to several limitations. The technique used by Regnard (1893), based on the assumption that water rotating in the vessel was moving at the same velocity as the vessel itself, does not correct for the decided lag that exists between the speeds of the container and the water rotating in the container. The methods used by Fry and Hart (1948), Davidson (1949), and Brett, Hollands, and Alderdice (1958), although able to measure surface water velocities, cannot be used to determine any differences in velocities which might exist between surface and lower water layers. To date the Leupold and Stevens meter used by Paulik, DeLacy, and Stacy (1957) has been the best reported method for determinations of water velocities in the fish wheel experiments. Unfortunately, the meter is a delicate instrument and must be handled with extreme care. In addition, at Boothbay Harbor, it has been found to be usable only in fresh water, since the electrolysis that occurs in salt water interferes with operation of the meter by forming deposits on the contacts.

None of the devices used previously in swimming-speed determinations meet the specifications required for the present studies.[1/] For this reason, a new photoelectric cell-type current meter, using a modified 1-shot cathode-coupled multivibrator circuit, has been planned, built, and tested. This meter cannot be used to determine the velocities at the surface or the immediate sides or bottom of the container. However, these limitations do not appear serious, for the fish swims infrequently in these regions for any length of time and the current being measured is that actually encountered by the fish. The immersed part of the meter was designed to reduce as much as possible any interference with the water current.

It will be noted from the following illustrations and descriptions that the meter is sturdy and small enough to fit easily within the cage (previously described)

1/ Only the Gurley current meter, Model 622B-SW10 with Model 609-B counter, would seem to meet with most of the desired specifications. To date, use of this meter in swimming-speed studies has not been reported, and it was not tested in the present study.

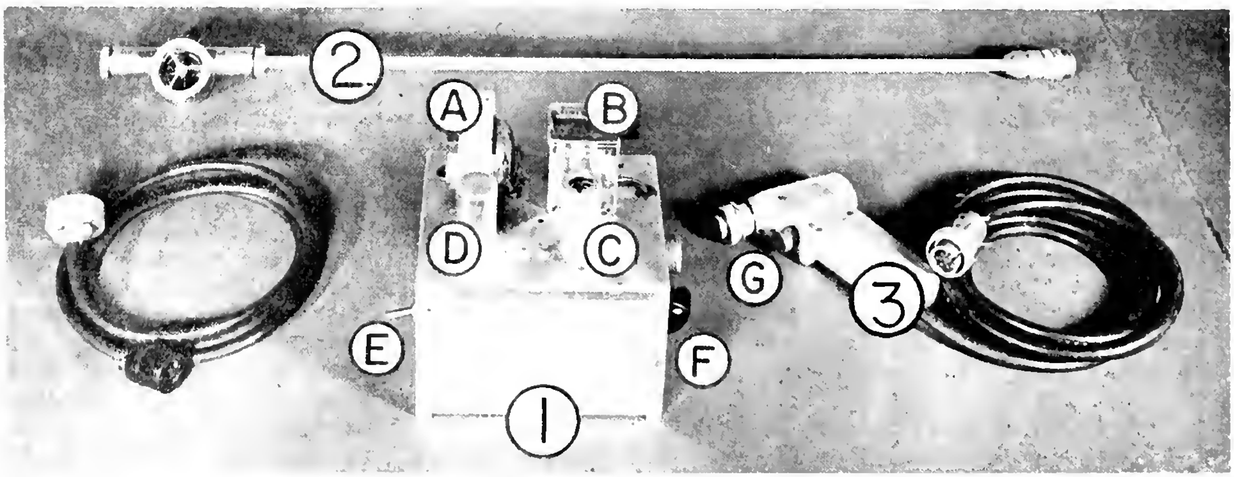

Figure 1. --Laboratory current meter, with parts labelled (wherever possible) to correspond with text.

and can record velocities in salt water and in fresh water, and can be used easily in the field as well as in the laboratory.

DESCRIPTION AND OPERATION OF THE METER AS DESIGNED FOR LABORATORY USE

The meter is made up of three main parts as shown in figure 1: chassis (1), rod assembly (2), and gun (3). Wherever possible, parts are labelled to correspond with the electrical diagram (fig. 3).

The chassis (5 inches long by 6 inches wide by 4 inches high) is constructed of aluminum (1/32 inch thick). It houses the 12AU7 tube, condenser, rectifiers, register counter, transformer, potentiometer, and main switch.

The rod assembly (fig. 2) is brass and houses the penlight lamp, photoelectric cell, and propeller. Parts of the assembly containing the lamp and the photoelectric cell have been made waterproof by silver- and soft-soldering. The photoelectric cell is further sealed from contact with water with plastic resin. The propeller shaft is stainless steel mounted on bronze bearings.

The gun assembly, constructed of aluminum, houses the contact-register counter switch.

When in operation, the rod assembly is submerged in the water to the desired depth. Care should be taken to be certain that the propeller assembly is in direct line with the water flow. The test is begun by closing the switch (E) and releasing

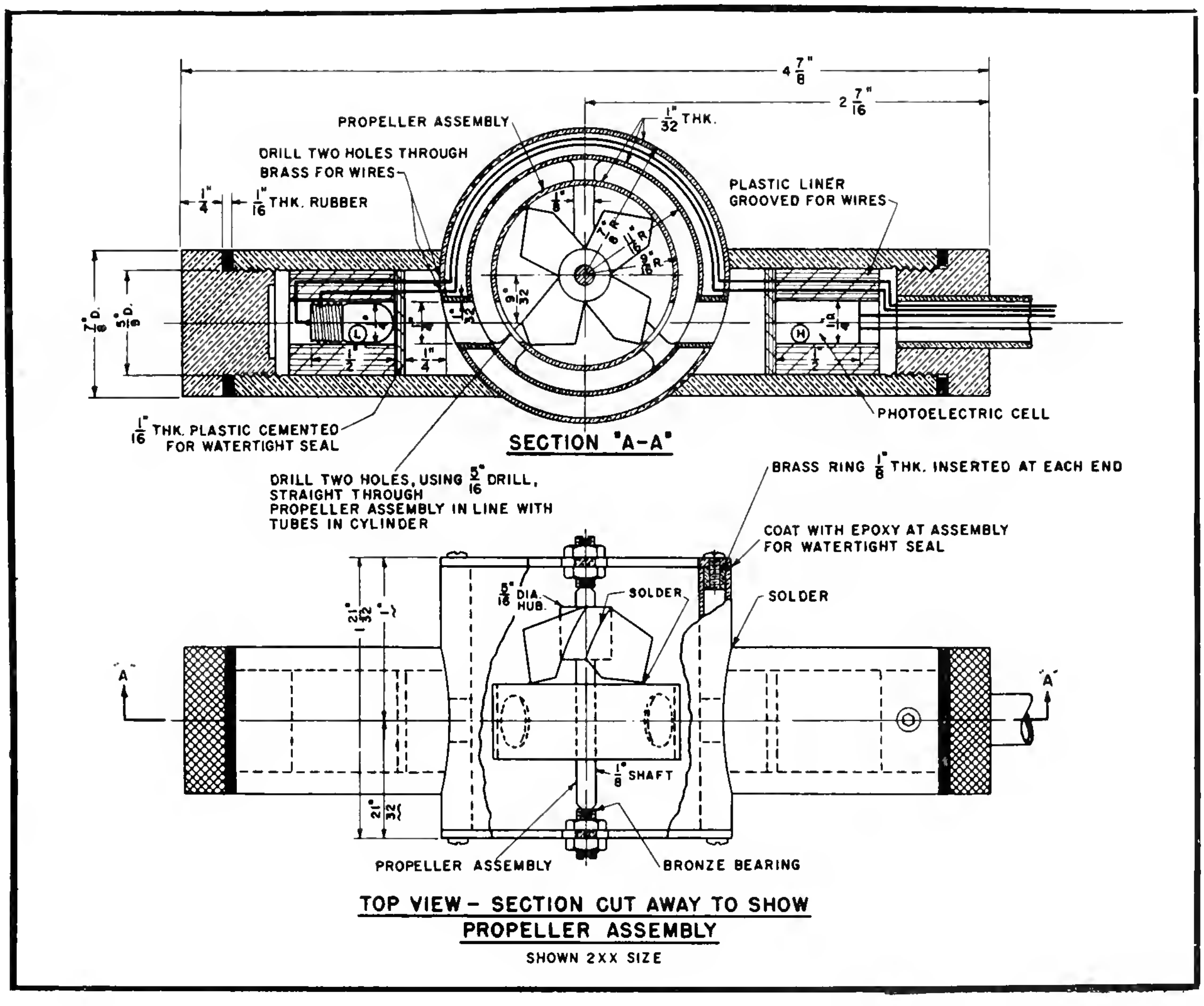

Figure 2.--Detailed drawings of the portion of the rod assembly housing the bulb, photoelectric cell, and propeller.

the counter trigger switch (G). The potentiometer (F) should then be adjusted so that impulses are being received evenly on the counter. The register counter (B) is reset to 0, and the actual tests are begun.

The power supply of the unit operates on a 110-volt source, switched on by E and provides a voltage of approximately 190 for the plates of the 12AU7 tube (C) and for the photoelectric cell (H) (fig. 3). The 12AU7 tube is a dual triode tube which acts as two independent switching units (J and K). When only background light falls on the photoelectric cell, by means of resistances R_1 and R_2, a bias voltage is set just sufficient to permit unit K to conduct. The resistance R_4 establishes bias on the grid of section J which keeps this section from conducting. When light falls on the photoelectric cell from the lamp (L), by means of resistance R_3, the bias voltage on unit J becomes less negative, and that on unit K more negative than previously. This causes unit K to cease conducting and unit J to begin conducting. The relay (I) in series with section J is then energized, activating the register counter circuit. Every time the openings in the propeller assembly (fig. 2) are in direct line with the openings of the lamp and photoelectric cell units, light can fall on the photoelectric cell and an impulse is received on the register counter. This impulse is recorded on the register and represents a complete revolution of the propeller. When the holes are no longer lined up, the bias voltage on unit J becomes more negative while the bias voltage on unit K becomes less negative. This allows the relay to return to its normal open position and the circuit to come to equilibrium. The counter register records only when light falls on the photoelectric cell, and this occurs when the propeller makes a complete revolution.

DESCRIPTION AND OPERATION OF THE METER AS DESIGNED FOR FIELD USE

The field meter, like the laboratory meter, is made of three main parts: chassis (1) , rod assembly (2), and gun (3) (fig. 4). As with the laboratory meter illustrations (figs. 1, 2, and 3), wherever possible, parts in figure 4 have been labelled to correspond with the electrical diagram (fig. 5).

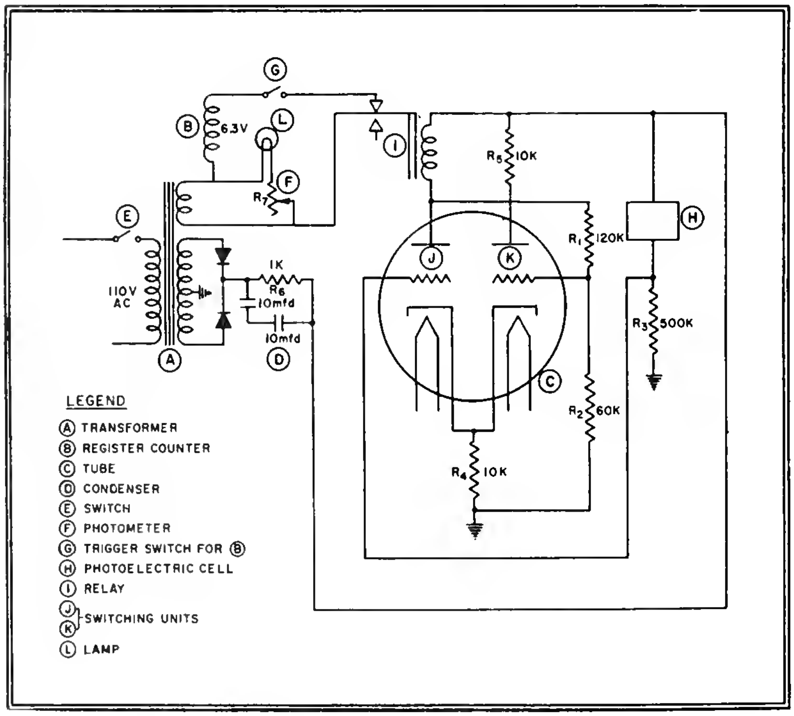

Figure 3.--Electrical diagram of the laboratory current meter.

The chassis (12 inches long by 8 inches wide by 3 inches high) is constructed of steel (1/32 inch thick). It houses transistors (2N94A), potentiometer, two 6-volt and two 9-volt batteries, register counter, relay, and main switch.

The rod and gun assemblies are identical with those used in the laboratory apparatus (figs. 1 and 2).

Operational procedure in the field is identical with laboratory procedure. The rod assembly is submerged in the water to the desired depth (limited by the length of the rod) and the test begun by closing the switch E and releasing the counter trigger switch (G). The potentiometer (F) is then adjusted so that impulses are being received evenly on the counter. The

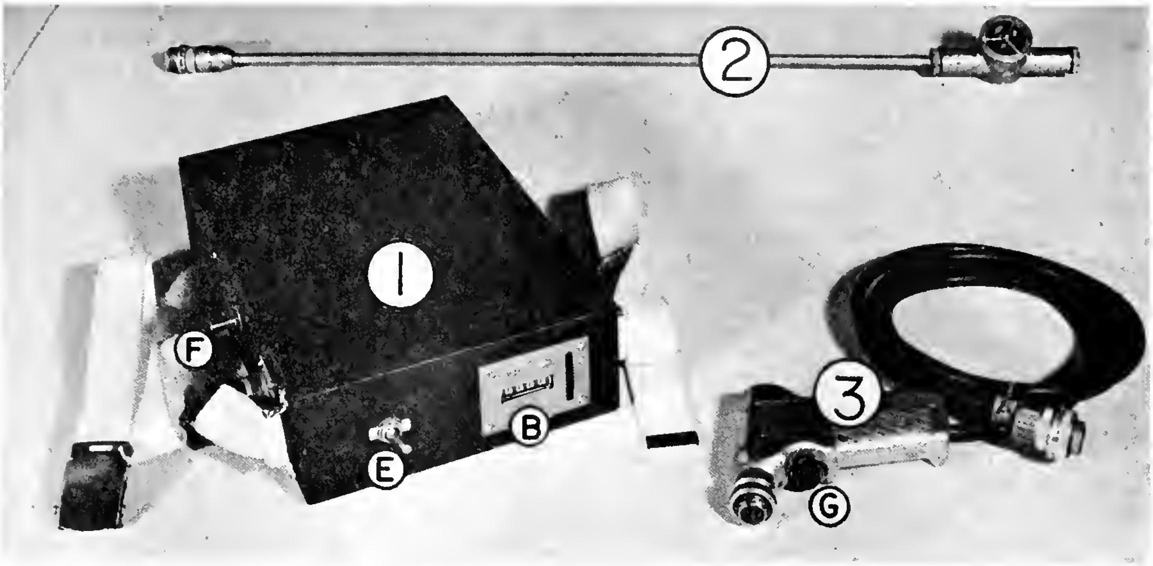

Figure 4.--Field current meter, with parts labelled (wherever possible) to correspond with text.

register counter (B) is reset to 0, and the actual tests are begun.

The 18-volt (two 9-volt) battery, switched on by E, is the power supply for the transistors (J and K) and the photoelectric cell (H). The transistors act as two alternately operating switching units. When only background light falls on the photoelectric cell, by means of resistances R_1 and R_2, the bias voltage is set just sufficiently enough to permit unit K to conduct. At the same time, resistances R_4 and R_6 establish bias on unit J which keeps it from conducting. When light falls on the photoelectric cell from the lamp (L), by means of resistances R_4 and R_3, the bias voltage on unit J becomes less negative and the bias voltage on unit K more negative. This causes unit K to cease conducting and unit J to begin conducting. The relay (I) in series with section J is then energized, activating the register counter circuit. When light from the lamp no longer strikes the photoelectric cell, the bias voltage on unit J becomes more negative and the bias voltage on unit K less negative. This allows the relay to return to its normal open position and the circuit to come to equilibrium. As previously stated, the counter register records only when light falls on the photoelectric cell which occurs when the propeller makes a complete revolution.

The meter has been calibrated by passing known volumes of water through the instrument at various speeds for known

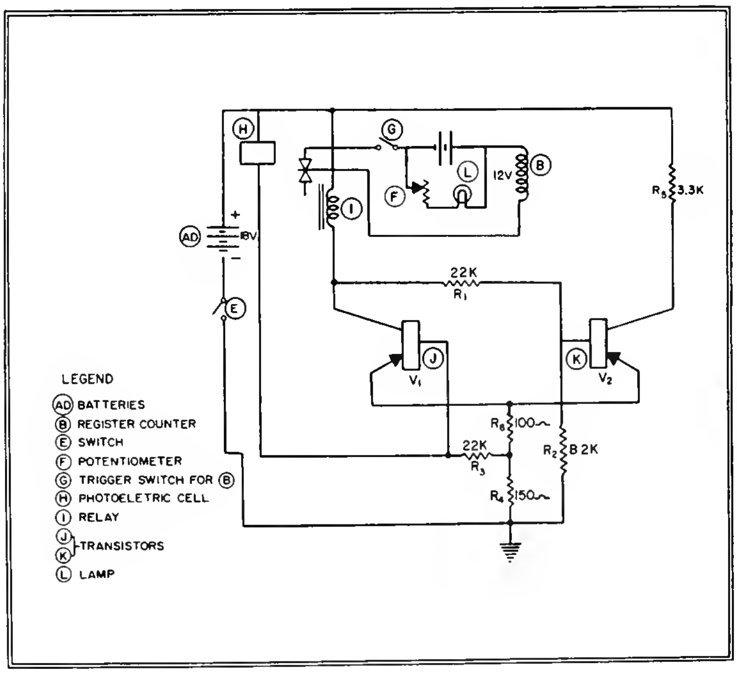

Figure 5.--Electrical diagram of the field current meter.

periods of time. A straight line relation (fig. 6) exists between the number of times the propeller, synchronized to the counter, makes a complete revolution, and the speed of the water in feet per second. Therefore, by merely making a note of the number recorded on the counter register for a given period of time, the velocity of the water being tested can be easily calculated or read from the chart. The meter in its present form will record speeds up to 6 miles per hour, and can be used at depths less than 3 feet. Greater speeds could be measured by changing the angle of the propeller assembly and recalibrating, while currents at greater depths could be determined by increasing the length of the rod. The maximum water velocity which could be measured by the meter has not been determined.

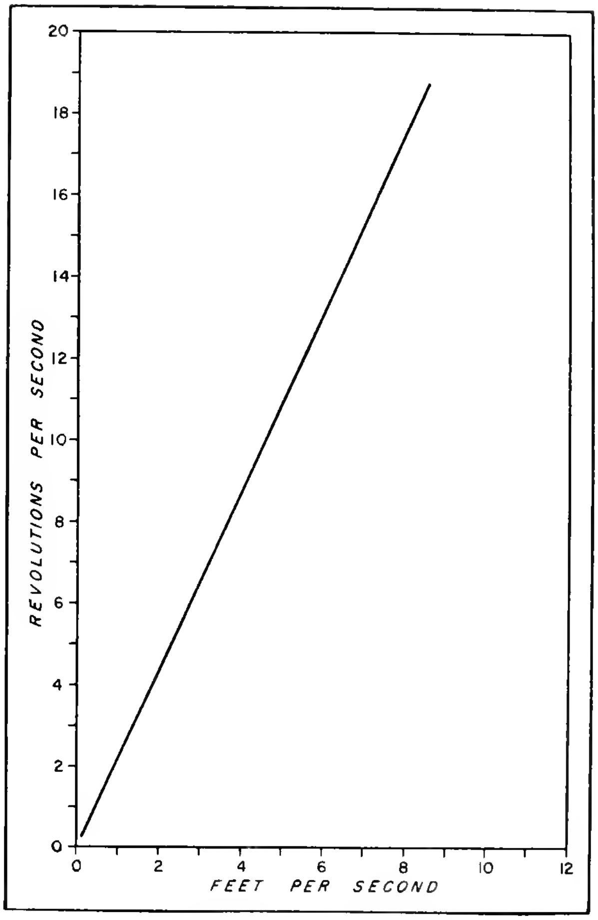

Figure 6.--Relation of revolutions per second to feet per second for the current meter.

SUMMARY

A photoelectric current meter based on a modified 1-shot cathode-coupled multivibrator circuit has been planned, built, and tested. It has been designed to record velocities in the laboratory or field under salt- or fresh-water conditions. In the laboratory it is powered by a 110-volt source and can record currents encountered by fishes in circular-tank experiments. In the field it is powered by two 9-volt batteries and has been designed to measure currents at depths less than 3 feet, and speeds up to 6 miles per hour. Greater speeds could be measured by changing the angle of the propeller and recalibrating.

ACKNOWLEDGMENTS

We wish to thank A. P. Stickney and Dr. C. J. Sindermann of the Bureau of Commercial Fisheries Research Laboratory at Boothbay Harbor, Maine, for valuable suggestions in preparation of this manuscript. We also wish to thank R. Stanley of Watertown, Massachusetts, for assistance in construction of the meter.

LITERATURE CITED

BRETT, J. R., M. HOLLANDS, AND D. F. ALDERDICE.
1958. The effect of temperature on the cruising speed of young sockeye and coho salmon. Journal of the Research Board of Canada, vol. 15, No. 4, pp. 587-604.

DAVIDSON, VIOLA.
1949. Salmon and eel movement in constant circular current. Journal of the Research Board of Canada, vol. 7, No. 7, pp. 432-448.

FRY, F. E. J., AND J. S. HART.
1948. Cruising speed of goldfish in relation to water temperature. Journal of Research Board of Canada, vol. 7, No. 4, pp. 169-175.

PAULIK, G. J., A. C. DeLACY, AND E. F. STACY.
1957. The effect of rest on the swimming performance of fatigued adult silver salmon. University of Washington, School of Fisheries,

Technical Report 31, pp. 1-21.

REGNARD, P.
1893. Sur un dispositif qui permet de mesurer la vitesse de translation d'un poisson se mouvant dans l'eau. Comptes Rendus Societe de Biologie, Paris, Ser. 9, No. 5, pp. 81-83.

Ms #889

INT.DUP.,D.C.60- 71409